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Specification and Drawings, as originally filed, with Application for Patent Serial No: **2,412,209**, on November 19, 2002, by **NOETIC ENGINEERING INC.**, assignee of Trent Michael Victor Kaiser, Maurice William Slack and Daniel Dall'Acqua, for "Moineau Stator".

PRIORITY DOCUMENT

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ABSTRACT OF THE DISCLOSURE

A Moineau stator includes a rigid support housing having walls able to resist pressure, torque, and axial loads experienced in its intended operating environment. A deformable lobed stator tube is supported within the support housing. The tube has an interior surface, an exterior surface, and lobes arranged in a configuration adapted to interact with a moineau rotor. The tube has walls that are sufficiently thin as to be subjected to elastic deformation in response to interfacial seal forces imposed by interference with the rotor. The tube is supported within the support housing, with pressure acting on the interior surface of the tube balanced with a substantially equal pressure acting on the exterior surface of the tube, such that the deformation of the tube in response to pressure variations is limited while the wall of the tube remains compliant to facilitate the tube tracking movement of the rotor.

TITLE OF THE INVENTION:

Moineau Stator

FIELD OF THE INVENTION

The present invention relates to a Moineau Stator which interacts with a rotor in either a pump or a motor application.

BACKGROUND OF THE INVENTION

PC pumps and mud motors ("Moineau pumps") of conventional design have a moulded elastomeric insert bonded firmly to the inside of a cylindrical case, usually made of steel. This comprises the stator of the pump or motor unit. The inside shape of the elastomer is formed with a cavity that has a helical characteristic that mates with a helically-shaped rotor. Interference between the two components creates seal lines that contain cavities of fluid which progress in the axial direction when the rotor is rotated relative to the stator. If rotational power is applied to the rotor, the assembly functions as a pump against differential pressure. If differential pressure is applied across the assembly, rotary power is extracted from the rotor and the assembly functions as a motor.

When formed inside of a cylindrical case out of elastomer, the shape of the stator cavity requires the elastomer thickness to vary around the circumference. The locations where the thickness is greatest are subjected to the largest distortional elastomer stresses during operation. Cyclic stress developed in the elastomer by the seal location moving back and forth, or around the stator cavity generates heat in the core of the elastomer, which must be removed by conduction through the elastomer, either to the outer stator casing or to the inner surface of the elastomer where it is convected to the transported fluid.

In conventional designs, the largest heat-generation rate occurs where the ability to remove the heat is lowest. If it over-heats, the elastomer can fail and the function of the pump/motor is compromised. This has been a significant limitation in the performance and design of progressing cavity pumps and motors, and has led to the development of "uniform-thickness" elastomer designs, where the internal casing profile is provided to closely match the required stator cavity profile, and a relatively thin layer of elastomer is moulded to this surface to provide the final stator cavity geometry.

This approach has several advantages, including reduced heat generation and swelling characteristics. Several approaches have been developed for providing the relatively complicated internal profile from the high-strength material of the casing, including cold-rolling techniques, machining of the internal profile and the use of extrusion techniques. Some of these techniques are described in Canadian Patents 2,315,043 (Krueger et al) and 2,333,948 (Underwood et al).

In profiled stators, a thin elastomer layer is less compliant to indentation and requires less interference to obtain a seal capacity comparable with a thick-layered configuration. However, this renders the assembly more sensitive to manufacturing tolerance variations by increasing the seal strength variation associated with a given tolerance variation. The result is either a requirement for smaller tolerance variations or a pump or motor that requires excessive nominal rotor/stator interference to provide the required seal capacity. Reducing the magnitude of tolerance variations generally increases the cost of the manufacturing process, while excessive interference imposes higher forces on the intermediate layer without a corresponding increase in seal

capacity.

SUMMARY OF THE INVENTION

What is required is a profiled Moineau stator that is better able to manage interfacial seal forces, particularly to accommodate tolerance variations.

According to the present invention there is provided a Moineau stator which includes a rigid support housing having walls able to resist pressure, torque, and axial loads experienced in its intended operating environment. A deformable lobed stator tube is supported within the support housing. The tube has an interior surface, an exterior surface, and lobes arranged in a configuration adapted to interact with a moineau rotor. The tube has walls that are sufficiently thin as to be subjected to elastic deformation in response to interfacial seal forces imposed by interference with the rotor. Means are provided for supporting the tube within the support housing, including means for balancing pressure acting on the interior surface of the tube with a substantially equal pressure acting on the exterior surface of the tube, such that the deformation of the tube in response to pressure variations is limited while the wall of the tube remains compliant to facilitate the tube tracking movement of the rotor.

In accordance with the teachings of the present invention a force is exerted upon the exterior surface of the tube to counteract forces acting upon the interior surface of the tube. In the absence of pressure being exerted upon the exterior surface of the tube, the tube would tend to "balloon" as a result of internal pressure.

In one embodiment of the present invention, the support

housing is provided with lobes arranged in a configuration adapted to interact with the lobes on the tube. The lobes on the support housing serve to balance pressure acting on the interior surface of the tube, by exerting a substantially equal pressure upon the exterior surface of the tube to limit deformation of the tube in response to pressure variations. Although beneficial results may be obtained through the use of this embodiment, even more beneficial results may be obtained when either the exterior surface of the tube or an interior surface of the support housing is coated with an elastomer coating.

In another embodiment of the present invention, discrete pressurized axial cavities are positioned in an annulus between the tube and the support housing. Means is provided to equalize pressure in the axial cavities with pressure within the interior of the tube. The pressure acting on the interior surface of the tube, is thereby counterbalanced with a substantially equal pressure within the axial cavities acting on the exterior surface of the tube. This is another way of limiting deformation of the tube in response to pressure variations. There are various ways to equalize pressure. In the embodiment which will hereinafter be described, the means to equalize pressure includes fluid passages allowing fluids from the interior of the tube to communicate with the axial cavities.

In accordance with the teachings of the present invention, the thickness of the thin-walled profiled stator housing is reduced to the extent that a significant portion of the compliance of the stator is obtained by housing wall deflection. This allows for the use of a thinner intermediate layer without encountering the tolerance sensitivity exhibited by housings with more rigid walls. The

thinner intermediate layer is also likely to form a seal of consistently higher capacity without an increase in the total interfacial force. In the limiting case, the intermediate layer is reduced to a thin perhaps stiff coating or removed completely.

The increase in seal compliance of the thin-walled profiled stator housings also increases deflection under loads such as internal pressure, torque, and axial load that are incurred during operation. The thin-walled profiled stator housing is, therefore, surrounded by a coaxially positioned support housing capable of reacting the majority of the total pump or motor pressure differential. As described above, this support housing can either be cylindrical or may have lobes, at least on its interior surface, where said interior lobes are arranged as if comprising an additional external stator in relation to the lobed stator exterior as if acting as a rotor. Means to transfer radial load from the exterior of the thin walled stator to the interior of the support housing is provided largely by material placed in the annular space between the stator and support housing arranged to limit the pressure differential across the thin walled stator to prevent its excess expansion or collapse. The material placed in the annular space is preferably a fluid with means to control its pressure. The annular space is more preferably arranged to allow for a variation of the annular fluid pressure along the stator length to generally equalize the pressure between the annulus and stator interior. Variation of the annular fluid pressure is supported by providing a plurality of generally axially distributed discrete cavities, sealing segregated from each other.

When the support housing has internal lobes arranged in relation to the thin walled stator as described above, it

will be appreciated that a plurality of generally axially distributed cavities is formed. In such case it is preferred that the tube have an exterior surface coated with elastomer to more readily sealingly engage the interior surface of the lobed support housing and thus provide a more positive fluid seal between adjacent cavities.

When the support housing is provided as a cylinder, one or more axially distributed bulkheads are placed in the annulus between the tube and the support housing. Said bulkheads are arranged to attach to at least one of and sealingly engage both the tube and support housing thus creating axially distributed discrete cavities.

There are various means which can be used to equalize pressure between the cavities thus formed and the stator interior. There will hereinafter be illustrated and described a method which involves providing fluid passages which allow fluids from the interior of the tube to communicate with the axial cavities.

Another aspect of the present invention provides a second means of reducing the tolerance sensitivity of interfacial seal forces acting between the rotor and stator components. This implementation is based on the concept that the compliance of the intermediate layer to indentation is not the same at all circumferential locations in the cross-section. This compliance is generally much lower where the curvatures of the rotor and stator profiles are similar, in particular at points where the rotor and stator lobes are coincident and the inner stator profile is concave. By providing preferential variations in elastomer thickness, the compliance of the intermediate layer and housing at various circumferential points can be adjusted to provide an interfacial force distribution that is not as sensitive to

dimensional tolerance variations of the rotor and stator. When implemented correctly, this has the effect of minimizing the required interfacial seal force for a given seal strength.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features of the invention will become more apparent from the following description in which reference is made to the appended drawings, the drawings are for the purpose of illustration only and are not intended to in any way limit the scope of the invention to the particular embodiment or embodiments shown, wherein:

FIGURE 1 is a perspective view of a uniform thickness Moineau stator.

FIGURE 2 is a cross-sectional view of a uniform thickness Moineau stator with thin walls.

FIGURE 3 is a cross-sectional view of the uniform thickness Moineau stator with thin walls illustrated in **FIGURE 2**, with a cylindrical support housing.

FIGURE 4 is a side elevation view, in section, of the uniform thickness Moineau stator with thin walls illustrated in **FIGURE 2**, with a cylindrical support housing and discrete pressurized axial cavities.

FIGURE 5 is a cross-section view of the uniform thickness Moineau stator with thin walls illustrated in **FIGURE 2**, disposed within a multi-lobed support housing.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The preferred embodiments, implementations of a profiled Moineau stator generally identified by reference numeral 10, will now be described with reference to **FIGURES 1** through **5**.

Referring now to Figure 1, a stator 10 is shown comprised of a stator body 1 formed from a metal tube having a sidewall 2 into which a plurality of helically symmetric lobes 3 are placed, illustrated here as it would appear configured in a four lobe Moineau stator. An elastomeric liner 4 is disposed on the inside surface 5 of the stator body 1. The lobes 3 are placed by various manufacturing methods as described in the background.

Referring now to Figure 2, a stator 10 is shown in cross section as it would appear in its thin wall configuration. In this configuration, the thickness of the stator body 1 sidewall 2 is selected so that it will deflect under application of the rotor interference load, thus contributing a portion of the compliance required to accommodate the interference effecting the seal contact stress. This is advantageous as a means to reduce the demands placed on the elastomer layer 4, however it simultaneously reduces the pressure capacity of the stator body 1.

In applications where the thickness of the formed stator housing body 1 is insufficient to support operating loads, the stator 10 is preferably supported by a secondary containment vessel. In one embodiment, the secondary containment vessel is provided as a cylinder. Referring now to Figure 3, in this embodiment, a supported thin wall stator assembly 200 is shown in cross section where the thin walled stator body 1 is coaxially placed inside a cylindrical support housing 201 forming an internal annulus 202. With this configuration, the stator body 1 is readily supported as required to prevent its excess expansion or collapse by providing means to transfer radial load across the annulus 202. Such means may be provided by placing a compliant but relatively incompressible solid such as an elastomer in the annulus 202. Alternately radial load

transfer is readily provided by fluid pressure in the annulus 202 where, end closures are provided to sealingly attach the ends of stator body 1 to the cylindrical support housing 201 and the annulus 202 allowed to communicate with various of the fluid pressure points in the pump or motor application.

However, the fluid pressure is more preferably arranged to vary along the length of the stator 10 to generally equalize the pressure between the annulus and stator interior. It will be appreciated that control of pressure in these annulus cavities provides a means to reduce the pressure drop across the stator 10 and thus prevent overload of the stator body 1.

One novel means to provide such graduated pressure support is described now with reference to Figure 4 showing an interval of a supported thin walled stator assembly 200. Variation of the annular fluid pressure is supported by providing a plurality of generally axially distributed discrete cavities 203, sealing segregated from each other by bulkheads 204. The position of bulkheads 204 is maintained by spacers 205 contained within the support housing 201 and associated end closures. This configuration also provides a simple means of achieving accurate seal element spacing. Pressure equalization is provided by ports 206.

Referring now to Figure 5, in an alternate even more novel embodiment, a supported thin wall stator assembly 300 is shown in cross section where graduated pressure support is enabled by providing the support with a lobed support housing 301 configured in a hypocycloid geometry compatible with the stator 10 so that the stator 10 can be easily inserted into the lobed support housing. In this case, the lobed support housing 301 has one more lobe than the primary housing and a pitch defined by the ratio of secondary to primary hypocycloid lobes. Seals

between cavities are generated either through metal-to-metal seals or (more likely) through contact with an intermediate elastomer layer 302 applied to the outside of the stator 10 or inside of the lobed support housing 301. The cavities 303 are ported to the transported fluid to provide pressure equalization as required to prevent excess deformation of the stator 10. The cavities that terminate at either end of the motor section may be sealed to reduce risk of fluid migration along the cavities.

By providing a thin-walled stator 10 with a secondary housing, the stator housing geometry will be less expensive to fabricate than a single thick-walled primary housing. Using a formed secondary housing could simplify the task of creating an axial pressure distribution in the stator housing annulus provided the overall size of the motor is not prohibitive. Both of these approaches would provide additional compliance at the rotor/stator seal lines to accommodate tolerances, swelling and thermal expansion. This is a significant advantage over conventional uniform-wall designs, where the stiffness of the thin elastomer layer has low tolerance for such variations. Indeed, careful design of the thin-wall stator could reduce the required elastomer thickness or eliminate the requirement for an elastomer completely in many applications.

In this patent document, the word "comprising" is used in its non-limiting sense to mean that items following the word are included, but items not specifically mentioned are not excluded. A reference to an element by the indefinite article "a" does not exclude the possibility that more than one of the element is present, unless the context clearly requires that there be one and only one of the elements.

It will be apparent to one skilled in the art that

modifications may be made to the illustrated embodiment without departing from the spirit and scope of the invention as hereinafter defined in the Claims.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A Moineau stator, comprising:

a rigid support housing having walls able to resist pressure, torque, and axial loads experienced in its intended operating environment;

a deformable lobed stator tube supported within the support housing, the tube having an interior surface, an exterior surface, lobes arranged in a configuration adapted to interact with a moineau rotor and walls that are sufficiently thin as to be subjected to elastic deformation in response to interfacial seal forces imposed by interference with the rotor; and

means for supporting the tube within the support housing, including means for balancing pressure acting on the interior surface of the tube with a substantially equal pressure acting on the exterior surface of the tube such that the deformation of the tube in response to pressure variations is limited while the wall of the tube remains compliant to facilitate the tube tracking movement of the rotor.

2. The Moineau stator as defined in Claim 1, wherein the interior surface of the tube has an intermediate lining layer adapted to improve sealing as between the interior surface and the rotor.

3. The Moineau stator as defined in Claim 2, wherein the intermediate lining layer is an elastomer coating.

4. The Moineau stator as defined in Claim 3, wherein the elastomer is of uniform thickness.

5. The Moineau stator as defined in Claim 1, wherein an annulus between the tube and the support housing is filled with elastomer, thereby balancing pressure acting on the interior surface of the tube with a substantially equal force acting on the exterior surface of the tube such that the deformation of the tube in response to pressure variations is limited.

6. The Moineau stator as defined in Claim 1, wherein an annulus between the tube and the support housing is filled with fluid, thereby balancing pressure acting on the interior surface of the tube with a substantially equal pressure acting on the exterior surface of the tube such that the deformation of the tube in response to pressure variations is limited.

7. The Moineau stator as defined in Claim 1, wherein the support housing has lobes arranged in a configuration adapted to interact with the lobes on the tube, thereby balancing pressure acting on the interior surface of the tube with a substantially equal pressure acting on the exterior surface of the tube such that the deformation of the tube in response to pressure variations is limited.

8. The Moineau stator as defined in Claim 7, wherein one of the exterior surface of the tube or an interior surface of the support housing is coated with an elastomer coating.

9. The Moineau stator as defined in Claim 1, wherein discrete pressurized axial cavities are positioned in an annulus between the tube and the support housing and means provided to equalize pressure in the axial cavities with pressure within the interior of the tube, thereby balancing pressure acting on the interior surface of the tube with a

substantially equal pressure acting on the exterior surface of the tube such that the deformation of the tube in response to pressure variations is limited.

10. The Moineau stator as defined in Claim 9, wherein the means to equalize pressure includes fluid passages allowing fluids from the interior of the tube to communicate with the axial cavities.

11. A Moineau stator, comprising:

a substantially cylindrical rigid support housing having walls able to resist pressure, torque, and axial loads experienced in its intended operating environment;

a deformable lobed stator tube supported within the support housing, the tube having an interior surface, an exterior surface, lobes arranged in a configuration adapted to interact with a moineau rotor and walls that are sufficiently thin as to be subjected to elastic deformation in response to interfacial seal forces imposed by interference with the rotor;

the interior surface of the tube having an intermediate lining layer in the form of an elastomer coating of substantially uniform thickness adapted to improve sealing as between the interior surface and the rotor; and

an annulus between the tube and the support housing is filled with elastomer supporting the tube within the support housing, discrete pressurized axial cavities are positioned in the elastomer and fluid passages extend through tube and the elastomer to the axial cavities allowing fluids from the interior of the tube to communicate with the axial cavities, thereby balancing pressure acting on the interior surface of the tube with a substantially equal pressure acting on the exterior surface of the tube such that the deformation of the tube in response to pressure variations is limited while the wall of the tube remains compliant to facilitate the tube tracking movement of the rotor.

12. A Moineau stator, comprising:

a rigid support housing having walls able to resist pressure, torque, and axial loads experienced in its intended operating environment;

a deformable lobed stator tube supported within the support housing, the tube having an interior surface, an exterior surface, lobes arranged in a configuration adapted to interact with a moineau rotor and walls that are sufficiently thin as to be subjected to elastic deformation in response to interfacial seal forces imposed by interference with the rotor;

the interior surface of the tube having an intermediate lining layer in the form of an elastomer coating of substantially uniform thickness adapted to improve sealing as between the interior surface and the rotor; and

the support housing having lobes arranged in a configuration adapted to interact with the lobes on the tube, one of the exterior surface of the tube or an interior surface of the support housing being coated with an elastomer coating, an annulus between the tube and the support housing being filled with a fluid, the lobes of the support housing supporting the tube and localized pressure from the support housing together with fluid pressure, thereby balancing pressure acting on the interior surface of the tube with a substantially equal pressure acting on the exterior surface of the tube such that the deformation of the tube in response to pressure variations is limited while the wall of the tube remains compliant to facilitate the tube tracking movement of the rotor.

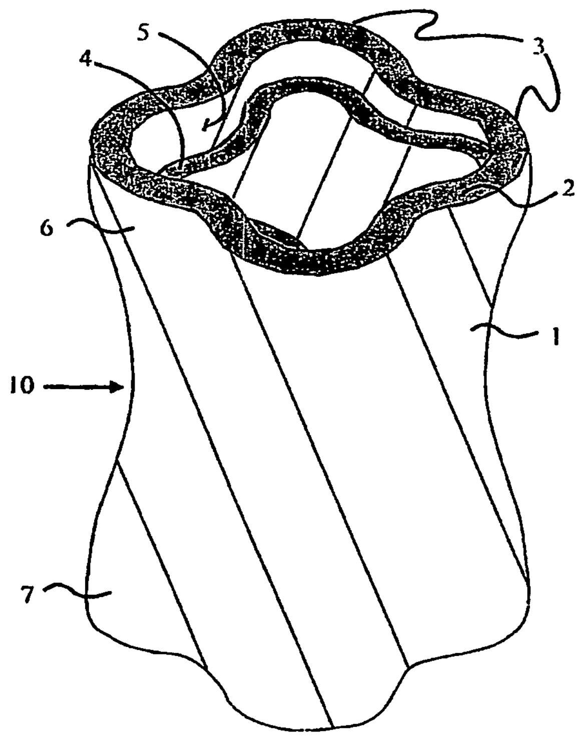

Figure 1. Profiled stator housing with constant elastomer thickness (4 lobe configuration shown).

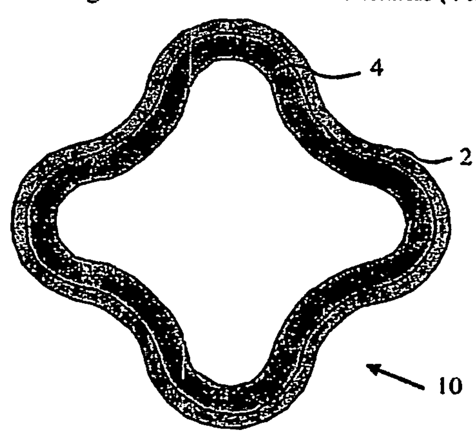

Figure 2. Axial cross-section of thin-walled profiled stator housing with constant elastomer thickness (4 lobe configuration shown).

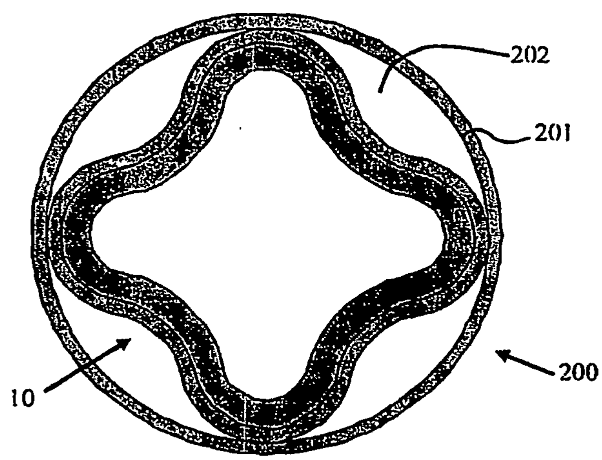

Figure 3. Axial cross-section of thin-walled profiled stator housing with constant elastomer thickness and cylindrical support housing (4 lobe configuration shown).

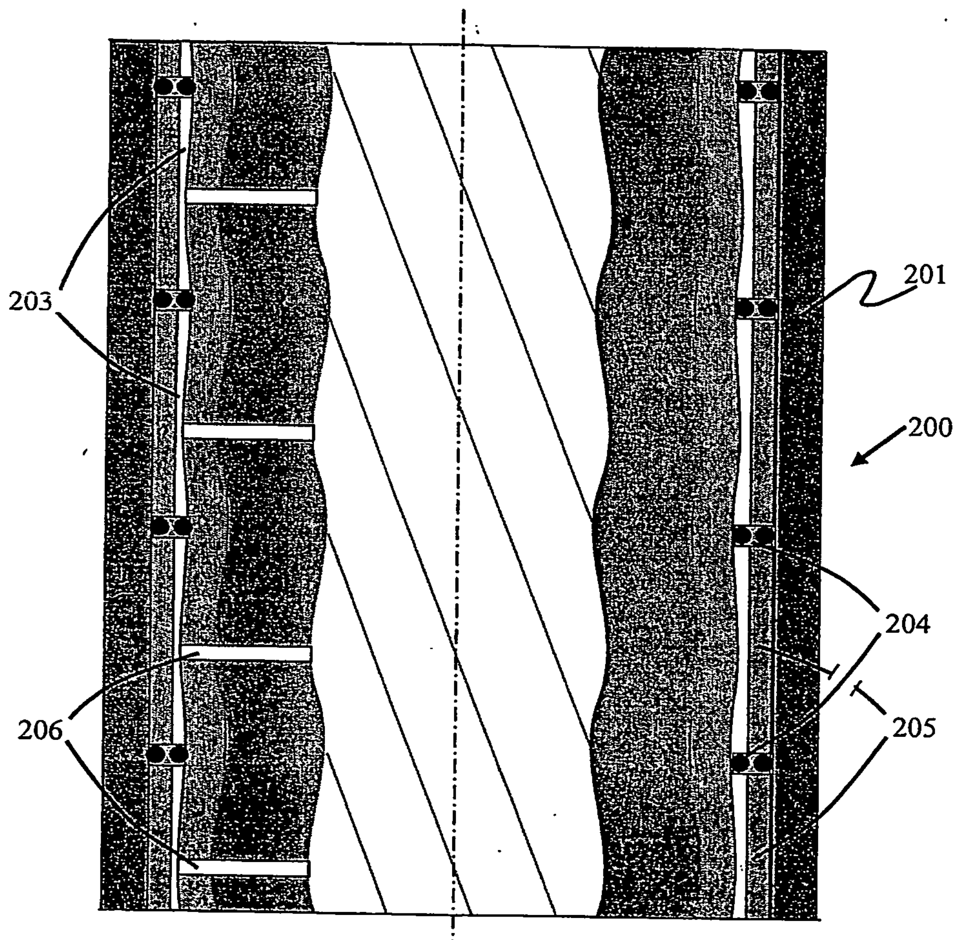

Figure 4. Longitudinal cross-section of a section of a sample staged thin-walled profiled stator housing with constant elastomer thickness, cylindrical support housing, and discrete pressurized axial cavities in the annulus between primary and secondary housings.

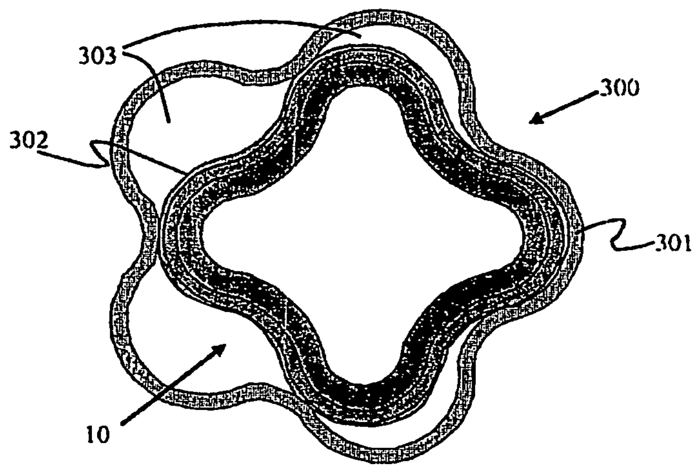

Figure 5. Axial cross-section of thin-walled profiled stator housing with constant elastomer thickness and multi-lobed support housing (4/5 lobe configuration with elastomer-coated primary housing shown).